

CHAPTER 2

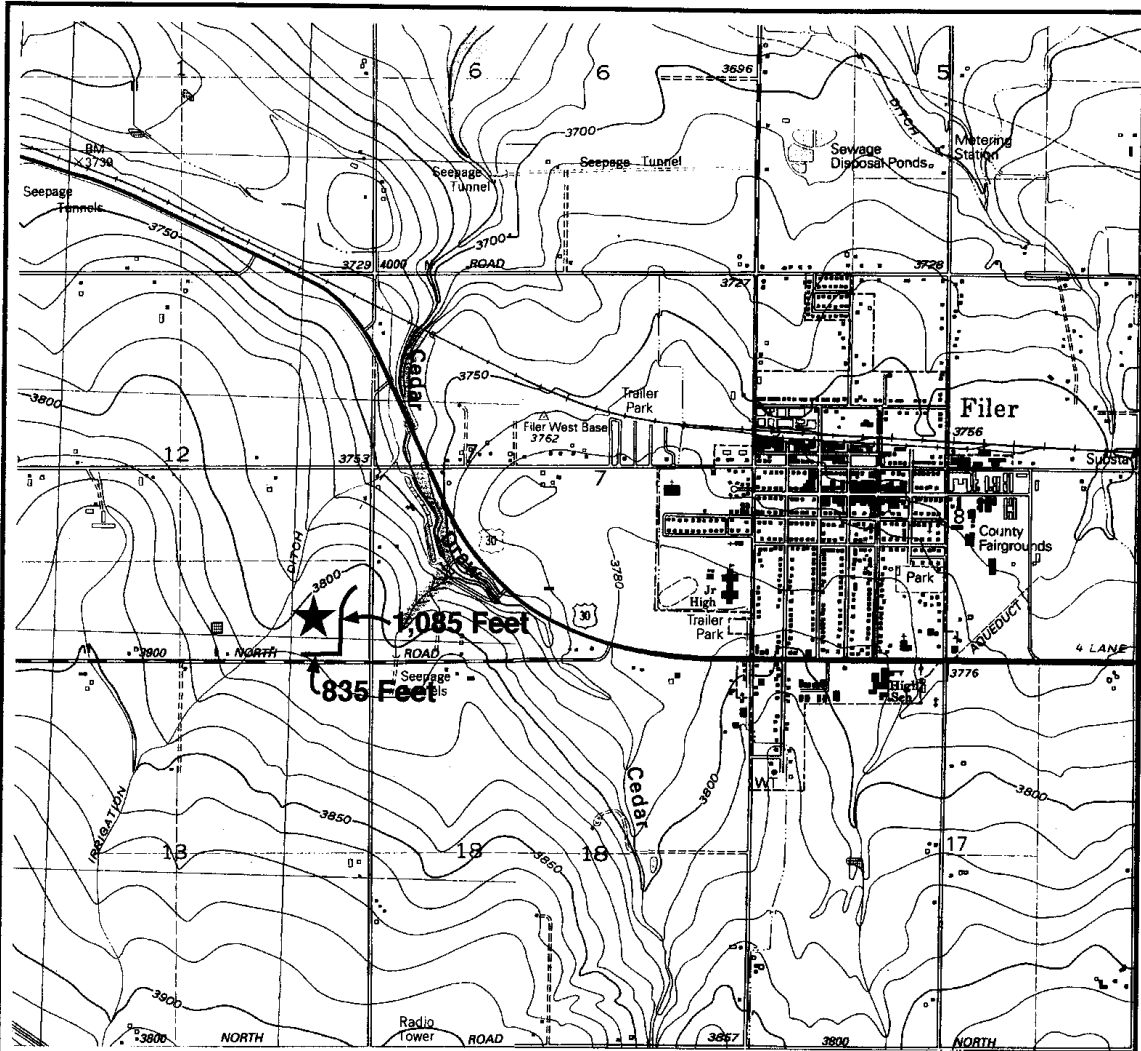
NEW TEST SECTIONS

Five new test sections were constructed during the previous 2 years. The new test sections are:

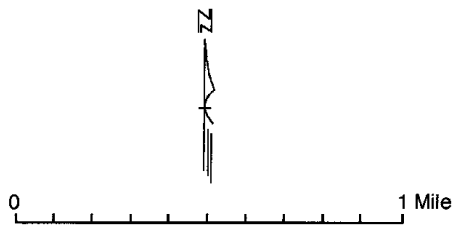
- TF-1 Exposed, 40-mil, wet-applied polyurethane geocomposite
- LO-1 Exposed, 45-mil, reinforced metallized polyethylene
- O-5 Exposed, 160-mil, bituminous geomembrane
- BU-1 Exposed, 60-mil, white textured HDPE
- BI-1 Exposed 20-mil EVA geocomposite

Test Section TF-1.—

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| Material: | Exposed, 40-mil, wet-applied polyurethane geocomposite over existing concrete |
| Date Installed: | June 2000 |
| Location: | Twin Falls, Idaho - about 7 miles west of town near Filer, Idaho (figure 1) (1,920 linear feet, 11,500 square feet) |
| Description: | Liner consists of 2 layers of 3-oz, heat-bonded, non-woven geotextile saturated with liquid polyurethane resin for a total minimum thickness of 40 mils. Geotextile is Linq Typar 3301 nonwoven, spunbonded, polypropylene geotextile (data sheet is in appendix A) |
| Prime Contractor: | Canal Lining Systems LLC with assistance from Ditch Line LLC |
| Process Developed by: | Payne Technology Companies Innovative Process Corporation (IPC) |
| Material Supplier: | Bayer Corporation |
| Surface Preparation: | <p>The land owner was responsible for surface preparation, including digging a 6-inch deep anchor trench on each side of the concrete ditch. The land owner's two to three man crew cleaned the concrete ditch by scraping with a shovel or hoe to loosen dirt and then shoveled out all dirt and debris. This level of surface prep was similar to other IPC jobs, such as a job in Pueblo, Colorado.</p> <p>Canal Lining Systems personnel reviewed the work and requested additional surface preparation to aid the wet-applied polyurethane in bonding to the concrete. Therefore, a 2,000-gallon water truck was rented (\$300/day), along with a high-pressure power washer (\$50/day) and four additional laborers for 1½ days. After jet cleaning, the dirt and debris were flushed through the canal into the drainage ditch. Final surface preparation looked very good. There remained only minimal dirt on the sidewalls and a few areas with some dirt in the ditch invert.</p> <p>On the morning of liner installation, a weedburner was used to remove any puddles or moisture left in the invert. The total cost for surface preparation is estimated at \$0.12 per ft² for a large job (a minimum of 100,000 ft²).</p> |
| Mobilization: | Mobilization costs for this liner can be significant because the lining machine weighs approximately 40,000 pounds and has to be trucked onto the site. Also, six to eight skilled workers from Canal Lining Systems LLC and from Bayer Corporation were needed on-site full-time. The amount of skilled labor may be reduced as this process becomes further developed. |



**1,920' Exposed Wet Applied
Geotextile / Polyurethane Composite**



**Location Map
Rick Stone Ranch
Canal Lining Installation**

Figure 1

| | |
|---------------------|---|
| Construction: | <p>The polyurethane resin consists of a mixture of polyol and isocyanate (about 2:1) with up to 10 percent accelerator, depending on the temperature. The Bayer chemists spent the first morning fine-tuning the mix proportions to achieve a gel time of 15-20 minutes, and settled on 5 percent accelerator to start the day (the chemicals were cool after sitting outside overnight). As the temperatures rose through the course of the day, the accelerator was gradually cut back to about 2 percent. The double layer of geotextile was run through a resin bath (dip pan) where it was saturated with liquid polyurethane. The 6-foot-wide membrane was then cut into lengths of approximately 16 feet. Four to six workers then carried the liner into the ditch and placed it over the existing concrete. The 6-foot width was perfect for this small ditch. The ditch perimeter was 5 feet, which allowed about 6 inches for placement into the anchor trench on each side. Although the machine can produce liner at speeds up to 16 feet per minute, the crew was capable of placing a 16-foot panel only every 2 minutes. Panels were shingled downstream and overlapped 6-12 inches. Three to five workers (including one IPC employee) then roll the liner into place, working out any bubbles and wrinkles, and pressing together the seams. The next day, batten strips were installed across the ditch every 100-150 feet, and polyurethane patching compound (Peter Putty) was mixed in 1-gallon baggies and used to patch around gated turn-outs and to perform minor repairs. A few gallons of polyurethane resin were left for the owner to perform any future repairs. The owner was also responsible for backfilling the anchor trenches.</p> |
| Difficulties: | <p>Areas of broken concrete were covered with a double layer of polyurethane liner. The liner will stop the water seepage, and may prevent further collapse of the canal. This lining technique was very labor intensive, requiring 5-6 skilled workers from Canal Lining Systems, 1-2 chemists from Bayer Corporation, and 6-10 unskilled laborers who were hired locally. Once production began, the lining machine produced a 16-foot panel about every 2 minutes. The crew had to really hustle to keep up and could not stop for breaks. The lining machine was operated for 2 to 2½ hours at a time. When shutting down for lunch and at the end of the day, the dip tank was flushed with acetone. Because of the hard physical labor, the crew could work only 4-5 hours each day. Depending on carry distance, two crews might be needed per machine. Perhaps with four to six additional laborers, a full, 8-hour work day could be achieved. The polyurethane is quite messy and ruins the workers clothes; it is recommend that disposable coveralls and booties be provided.</p> |
| Unit Cost Estimate: | <p>Exposed 40-mil wet-applied polyurethane over existing concrete = \$1.43 (\$0.75 Polyurethane Liner + 0.15 resin freight + 0.12 surface prep + 0.20 installation +17% OH and profit)</p> <p>Note: This does not include costs of \$5-\$10,000 for the transport of the lining machine and IPC personnel.</p> |
| Advantages: | <p>The 6-foot panel width was ideal for installation in this small, 5-foot perimeter, farm ditch. This liner is best suited for use over existing concrete because it bonds to the concrete to resist uplift. Bayer laboratory data shows bonded peel strength to smooth, clean concrete of 6-8 pounds per inch (appendix B). In the field, the liner did not appear to be continuously bonded to the concrete, and the peel strength to concrete, when applied under field conditions, appeared</p> |

significantly lower (1 to 2 pounds per inch?). Reclamation data on laboratory testing of liner and seams prepared in the field is included in appendix C.

Disadvantages:

Because this liner is manufactured in the field, consistency and quality control are less than they would be for a factory manufactured liner. Field manufactured liners are subject to variations of weather. Because the polyurethane reacts with water (foams), which reduces the bond and tensile strength, this liner absolutely cannot be installed in the presence of any rain or standing water. Wind also makes it very difficult to handle to the 6- by 16-foot wet panels, and the liner cannot be installed in winds above 20 mph. The 40,000-pound lining machine required good access to the canal.

The small panel size (6- by 16-foot) requires numerous field seams. Seaming is relatively easy, but Reclamation laboratory testing (appendix C) shows the seams are quite weak (peel strength of 1 to 2 pounds per inch).

Photographs:

1 through 22

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 1.—Existing concrete ditch with numerous cracks in the invert.



Photograph 2.—Some sections of the existing concrete are severely cracked with offsets up to 4 inches.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 3.—Power washing the ditch to remove dirt and sediment.



Photograph 4.—Ditch after power washing.
Subgrade preparation complete.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 5.—Severely cracked section after cleaning.



Photograph 6.—A section of the ditch where concrete panels are missing completely. A double layer of polyurethane liner will be installed over this section.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete

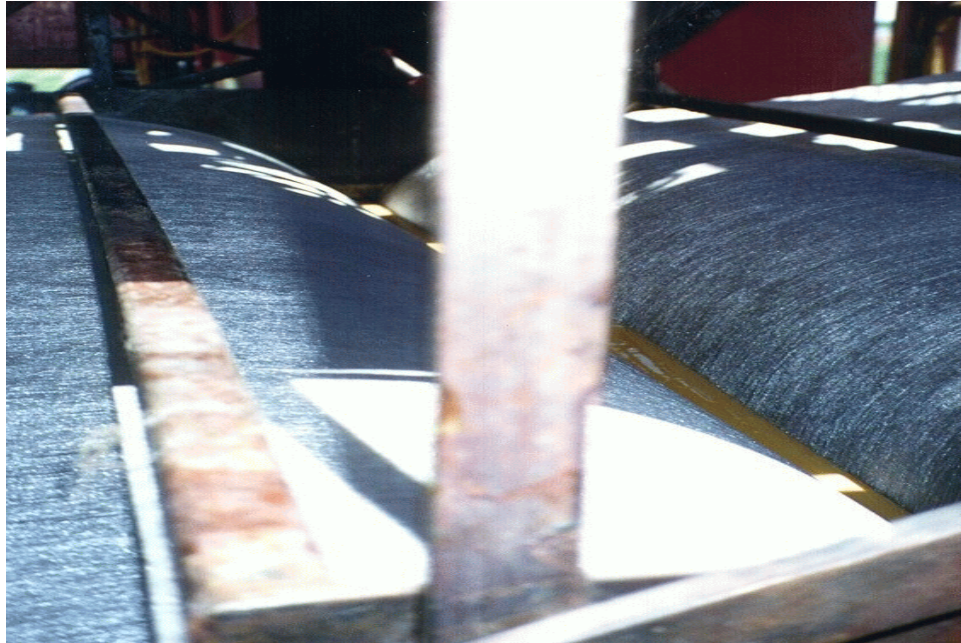


Photograph 7.—Before starting the job, chemists determine the proper mix ratios for Isocyanate, Polyol, and accelerator, depending on field conditions and temperatures.



Photograph 8.—Lining machine on flatbed trailer.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 9.—Two layers of geotextile are saturated with polyurethane resin as they pass through the dip pan.



Photograph 10.—Lining machine produces a 6- by 16-foot panel every 1 to 2 minutes.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 11.—Crew lays the 6- by16-foot panel over the existing concrete.



Photograph 12.—Laborers use rollers to work out wrinkles and improve adhesion to the concrete.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 13.—The liner is partially bonded to the old concrete. Foaming of the Polyurethane is caused by reaction with water



Photograph 14.—Large wrinkles were cut open and patched.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 15.—The chemists used a polyurethane patching compound to repair problem areas.



Photograph 16.—Chemist uses putty knife to trowel the patching compound.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 17.—Patching compound was used to bond the liner around slide gate turnouts.



Photograph 18.—Slide gate turnout with patching compound.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 19.—Batten strips were attached by pre-drilling holes and driving concrete anchors.



Photograph 20.—After pre-drilling, the 2-inch concrete anchors are easily hammered into the concrete. The 2-inch-wide batten strip is 16 gage stainless steel.

Stone Ranch Farm Lateral – Test Section TF-1
Exposed 40-mil Wet-Applied Polyurethane Geocomposite over existing concrete



Photograph 21.—The polyurethane liner conforms to concrete with offsets in the invert of up to 4 inches. The liner is ready to be secured by backfilling the anchor trench.



Photograph 22.—Ditch after installation was completed.

Test Section LO-1.—

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| Material: | Exposed 45-mil reinforced Metallocene with 8-oz geotextile cushion |
| Date Installed: | October 2000 |
| Location: | Lewiston Orchards - about 10 miles southeast of Lewiston Idaho (figure 2) (1500 + 300 linear feet, 36,000 square feet) |
| Description: | The 45-mil geomembrane consists of two layers of Metallocene reinforced with a 10 by 10 polyester scrim. The geomembrane is tan on the top side and black on the bottom. Metallocene is a copolymer blend of HDPE and Polypropylene. The material data sheet is included in appendix A. |
| Prime Contractor: | Lewiston Orchards Irrigation District (LOID) |
| Material Supplier: | Serrot Corporation |
| Surface Preparation: | <p>The irrigation district performed extensive subgrade preparation by removing vegetation from the canal, restoring the approximately 1½:1 side slopes and cutting a 2-foot wide bench for anchoring on each bank. The cost of subgrade preparation is estimated at \$0.26 per ft², based on the subgrade preparation costs of previous, similar test sections. The finished canal prism measures 20 to 24 feet across, including the 1 to 2 feet of material buried in the anchor berm on each bank. The finished canal invert measures 6 to 8 feet across, and the 1½:1 side slopes measure 3 to 4 feet high. Water typically runs about 2 feet deep, and this section of canal typically carries about 23 cfs. Seepage was estimated at 1 to 2 cfs and is quite evident in one bend where lots of vegetation is growing below the canal.</p> <p>The irrigation district also improved the access road by hauling in rock and gravel, and then grading the road. The road is only on one side of the canal. These costs are not included in the cost estimates.</p> |
| Construction: | <p>The Metallocene geomembrane is manufactured in 10-foot-wide rolls. The roll goods were then fabricated into 30- by 100-foot panels. The panels were folded toward the middle, and rolled onto the 10-foot cardboard core. A trackhoe was used to pre-position the panels and geotextile cushion along the canal.</p> <p>An eight-man crew installed the geomembrane. The crew first rolled out the geotextile cushion in the road and then pulled it into place. The crew then rolled out the geomembrane along the road, unfolded it, and pulled it into place, securing it temporarily with 3/8 inch rebar bent into a 1-foot-long pin. The trackhoe then covered the anchor berm with 6 to 12 inches of cover soil and rock. The geomembrane panels were shingled downstream, overlapped 1 to 2 feet, and welded with a hot-air gun and hand roller. Before seaming, the geomembrane was cleaned with wet cloth. Serrot provided a master welder.</p> |

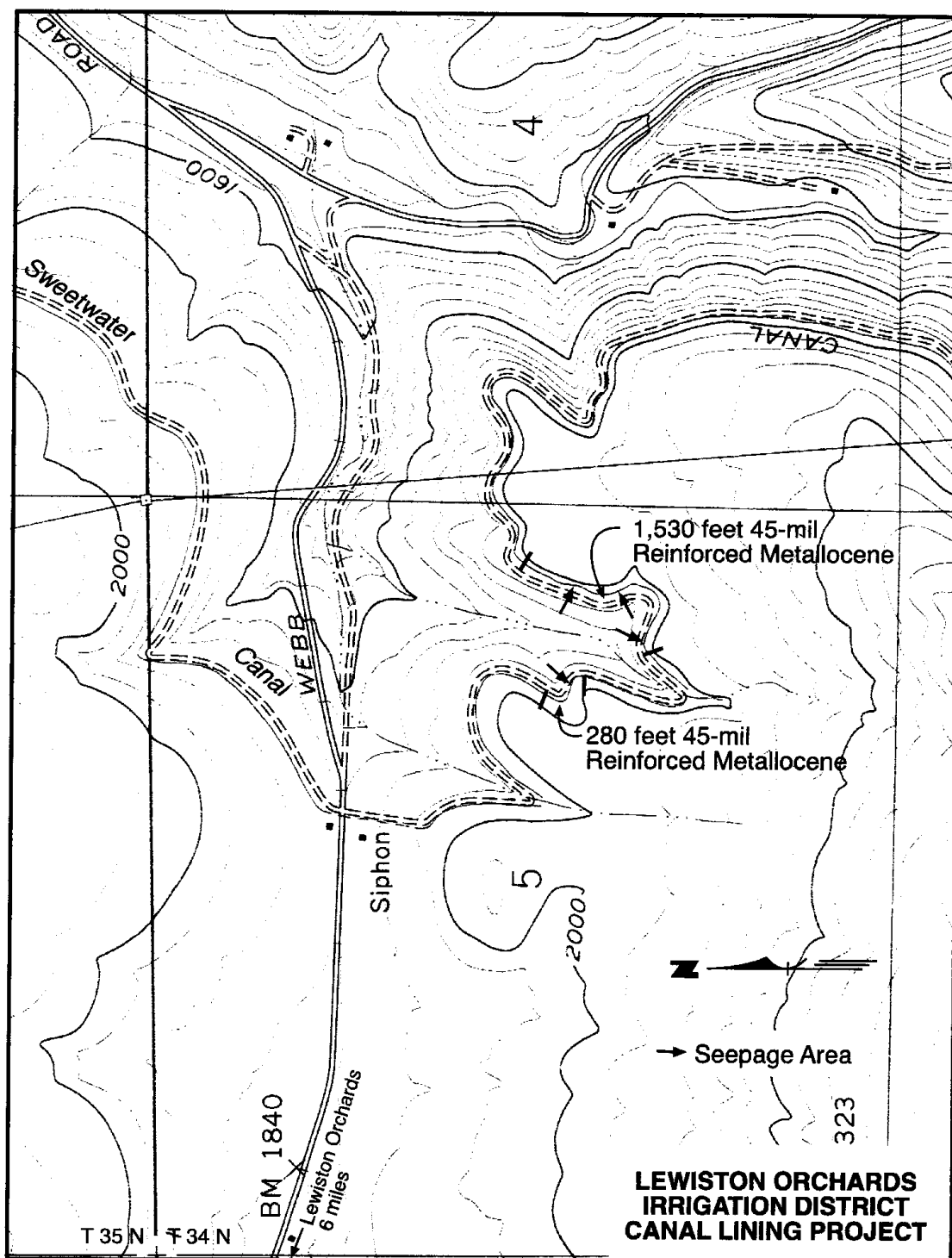


Figure 2 – Location Map

The first 600 feet of canal was quite rocky and was covered with a 16-oz geotextile cushion or excess scraps of Metallocene. The rest of the canal was much smoother, and cushion was placed in the invert only. Because of the liner flexibility, only the rockiest sections really needed the cushion. The cost estimate assumes an 8-oz geotextile cushion used everywhere.

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| Difficulties: | The wedge welder would not work on steep side slopes and over the rough subgrade. Also, there were problems with water in the canal invert. To get the liner up out of the mud, the welding was performed on 2- by 8-foot sheets of plywood. In the worst areas, a pump or wet-vac was used to dry out the canal invert before seaming. |
| Unit Cost Estimate: | Exposed 45-mil reinforced Metallocene with 8-oz geotextile cushion = \$1.00 per ft ² . (\$0.39 Metallocene + 0.10 Geotextile cushion + 0.26 surface prep + 0.10 installation +17% OH and profit) |
| Advantages: | The liner was very flexible and conformed to the subgrade easily. The 100-foot panels were easy to pull into place. A couple of panels were cut to fit around sharp bends in the canal, leaving welded seams every 50 to 100 feet. To minimize seaming on long sweeping bends, the liner was pleated and folded downstream. The only heavy equipment required was the trackhoe, which prepared the subgrade and unloaded and pre-positioned the rolls of geomembrane and geotextile cushion. The district should be able to perform minor repairs using a \$500 hot air welder. |
| Disadvantages: | Because the panels were fabricated into 30-foot widths and the canal prism varied from 20 to 24 feet, a lot of excess material was trimmed and wasted. The excess material was used as cushion in the invert, but it makes a very expensive cushion compared to 8 oz geotextile. A skilled welder was also needed at \$500+ per day to weld the field seams |
| Photographs: | 1 through 22 |

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 1.—Preconstruction conditions at Lewiston Orchards.
Subgrade consists of angular volcanic basalt.



Photograph 2.—Irrigation district removed a couple of abandoned pipe crossings to
facilitate lining installation.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 3.—Trackhoe reshapes the canal prism, restoring the 1½:1 side slopes.



Photograph 4.—Trackhoe cuts 3-foot anchor berm into both banks.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 5.—Trackhoe positions roll of geotextile cushion along the access road.



Photograph 6.—Geotextile cushion has been placed in the canal invert. The installation crew unrolls the Metallocene in the access road.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 7.—Crew unfolds the Metallocene and pulls the panel into place.



Photograph 8.—Installation crew pulls the Metallocene up the far bank and into final position.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 9.—At the downstream end, the liner is placed into a 3-foot-deep cut-off trench.



Photograph 10.—Liner is ready for seaming.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 11.—Liner is temporarily secured on the anchor berm with #3 rebar stakes.



Photograph 12.—To minimize seaming, the liner was folded around bends in the canal alignment.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 13.—Wet-Dry Vac used to remove ponded water before seaming.



Photograph 14.—Overlapped seams are cleaned to remove dirt and mud before seaming.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 15.—Master welder from Serrot uses hot-air welder to seam the Metallocene.



Photograph 16.—Plywood (not visible) is temporarily placed under the liner to provide a firm surface for seaming. Overlapped seams are clamped into final position for seaming.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 17.—As the seaming is completed, the plywood is removed.



Photograph 18.—The master welder places a large patch over a problem seam.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



Photograph 19.—Irrigation district personnel are trained in proper seaming techniques for any future repairs.



Photograph 20.—Trackhoe places cover material over the far anchor berm.

**Lewiston Orchards Irrigation District – Test Section LO-1
Exposed 45-mil Reinforced Metallocene**



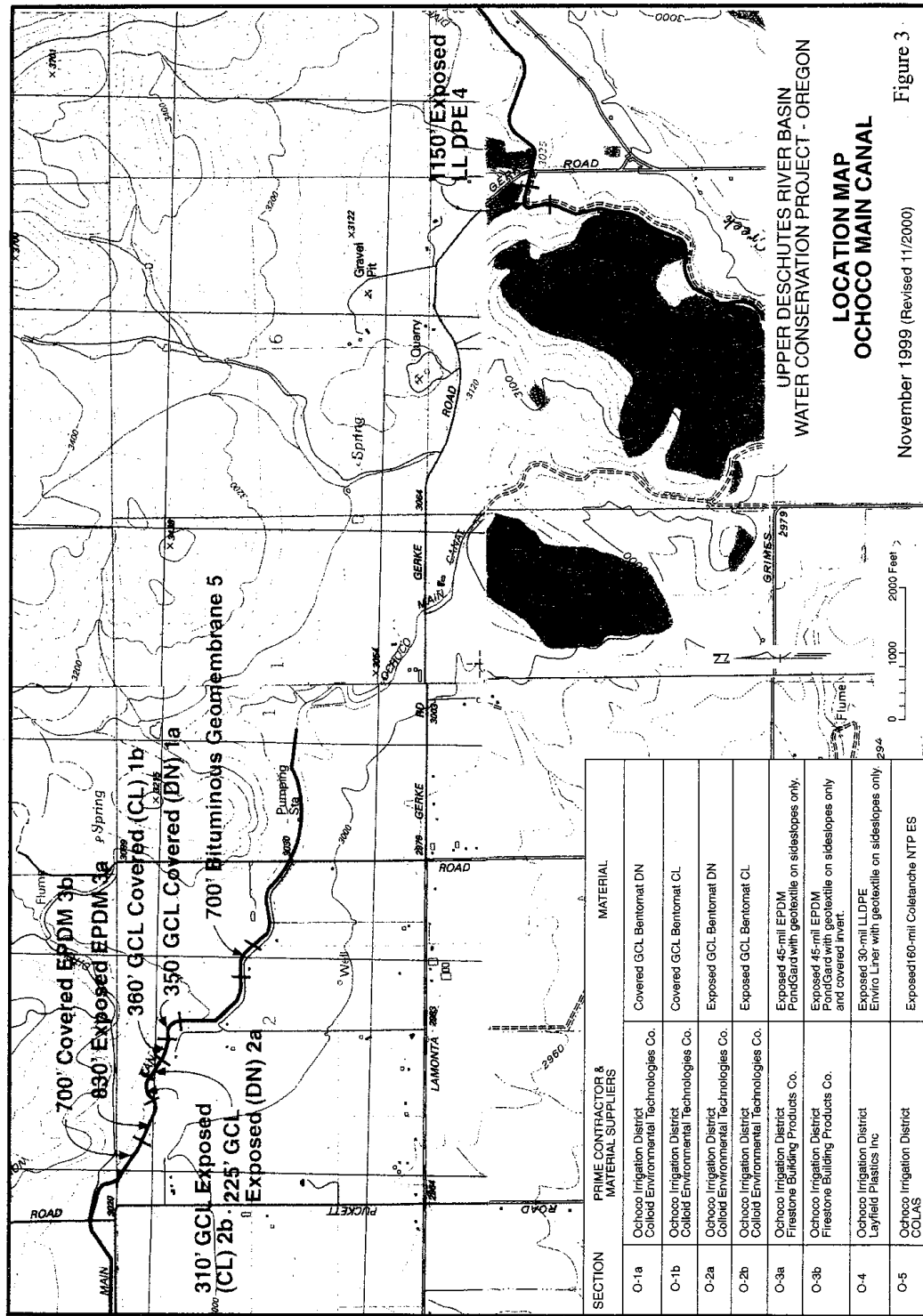
Photograph 21.—Additional road base was imported to restore the access road and to cover the near anchor berm.



Photograph 22.—Finished Metallocene installation.

Test Section O-5.—

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| Material: | Exposed 160-mil Coletanche NTP ES |
| Date installed: | November 2000 |
| Location: | Ochoco Irrigation District (figure 3) (700 linear feet; 28,000 square feet) |
| Description: | Coletanche NTP ES (Coletanche) is an elastomeric bitumen geomembrane, combining Styrene-Butadiene-Styrene (SBS) polymer and asphalt with a polyester reinforcement. COLAS manufactures five grades of Coletanche. Only the Coletanche ES is polymer modified. Coletanche is 160-mils thick and is provided in roll widths of 4 and 5 meters (13 and 16.5 feet). Product data sheets are included in appendix A. |
| Prime Contractor: | Ochoco Irrigation District |
| Material Supplier: | COLAS, Inc. (France) |
| Subgrade prep: | Ochoco personnel performed extensive subgrade preparation by removing vegetation that had overgrown the canal. They removed 6 to 12 inches of mucky sediment and restored the original 1½:1 side slopes. The cost for extensive subgrade preparation is estimated at \$0.26 per ft ² . This subgrade estimate was based on the subgrade costs of previous, similar test sections. The finished canal prism measures about 40 to 42 feet across, including a 1-foot V-notch anchor trench on each bank. |
| Construction: | Installation began at the downstream end of the test section and proceeded upstream 700 linear feet. The Coletanche was delivered in rolls measuring 5 by 80 meters (16½ by 262 feet), and the rolls were installed across the canal. The Coletanche rolls were handled by a trackhoe equipped with a lifting bar (constructed by the district). The Coletanche was first unrolled 4 to 5 feet by hand and clamped between 2 by 4s with a pair of C-clamps. A chain connected the C-clamps to a backhoe on the opposite bank. The backhoe then drove away from the canal, unrolling the Coletanche into place. The Coletanche was then cut to match the canal width and pulled into final position by a four-man crew. Adjacent sheets were overlapped 6 to 12 inches, shingled downstream, and seamed with a propane torch by a two-man crew. Finally, the membrane was secured in the berm by nailing, and then backfilled with 6-12 inches of cover soil in the V-notch anchor trench. At the upstream and downstream ends of the test section, the Coletanche was buried in a 2-foot- by 5-foot-wide cut-off trench. The upstream cut-off was backfilled with concrete, and the downstream was backfilled with soil. |
| Difficulties: | The subgrade was quite irregular, with offsets of up to 6 inches. Seaming over these large offsets was challenging. |



Unit Cost Estimate: Exposed 160-mil Coletanche = \$1.51 per ft²
(\$0.93 Coletanche + 0.26 preparation + 0.10 installation + 17% overhead (OH) and profit)

Advantages: Coordinating the movements of the trackhoe and the backhoe on opposite banks allowed precise positioning of the Coletanche, and little to no handling was required. Because each panel of the Coletanche was trimmed to match the canal prism, little to no material was wasted. Installation was fast and simple and required no special equipment. Irrigation districts can install this material with their own forces, thus allowing flexibility in the construction schedule to accommodate bad weather and fluctuating workload. This crew had experience installing other geomembranes and was able to install 32,000 square feet (7½ rolls) on the first day. By using their own equipment and labor, the irrigation district was able to install the membrane at significantly less cost than hiring a contractor.

Disadvantages: Because the Coletanche was installed across the canal, a transverse seam was needed every 5 meters along the canal. Seaming was rather slow, and two seaming crews were needed to keep pace with the installation crew. Exposed geomembranes are susceptible to weathering (especially UV light), animal damage, and vandalism. The Coletanche is UV resistant, and quite resistant to animal damage. Based on our experience with similar products, the expected service life is 20 to 40 years.

Photographs: 1 through 23



Photograph 1.—Earthen dike at upstream end of the test section. Preconstruction conditions are visible upstream from the dike.

Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES



Photograph 2.—The irrigation district reshaped the canal prism, restored the 1½:1 side slopes, and cut a 6-inch deep V-notch anchor trench on each bank.



Photograph 3.—The subgrade was quite rough, and offsets were up to 6 inches.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 4.—Geomembrane is placed in the cut-off trench at the downstream end of the test section.



Photograph 5.—Concrete placed over geomembrane in the upstream cut-off trench.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 6.—Completed upstream cut-off trench.



Photograph 7.—Trackhoe unloads rolls of Colas geomembrane from shipping container.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 8.—Trackhoe equipped with lifting bar (fabricated by the irrigation district) handles the rolls of geomembrane.



Photograph 9.—Close-up of lifting bar.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 10.—District used 2 by 4s and clamps to grip the geomembrane.



Photograph 11.—Geomembrane is pulled off the roll and into the canal.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 12.—Small frontloader pulls the geomembrane up the far bank and into position.



Photograph 13.—Geomembrane easily supports worker while suspended across the canal.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 14.—Trackhoe and front loader coordinate precise placement of the geomembrane liner.



Photograph 15.—Overview of liner placement.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 16.—After positioning, the liner is cut to length with little or no waste.



Photograph 17.—A propane torch is used to seam the geomembrane.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 18.—After heating with the torch, seams are pressed together with a paint roller.



Photograph 19.— Seamer places a large patch over a wrinkled seam caused by uneven subgrade.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



Photograph 20.—Ultrasonic testing of the seam.



Photograph 21.—The grader backfills the V-notch anchor trench.

**Ochoco Irrigation District – Test Section O-5
Exposed 160-mil Coletanche NTP 2 ES**



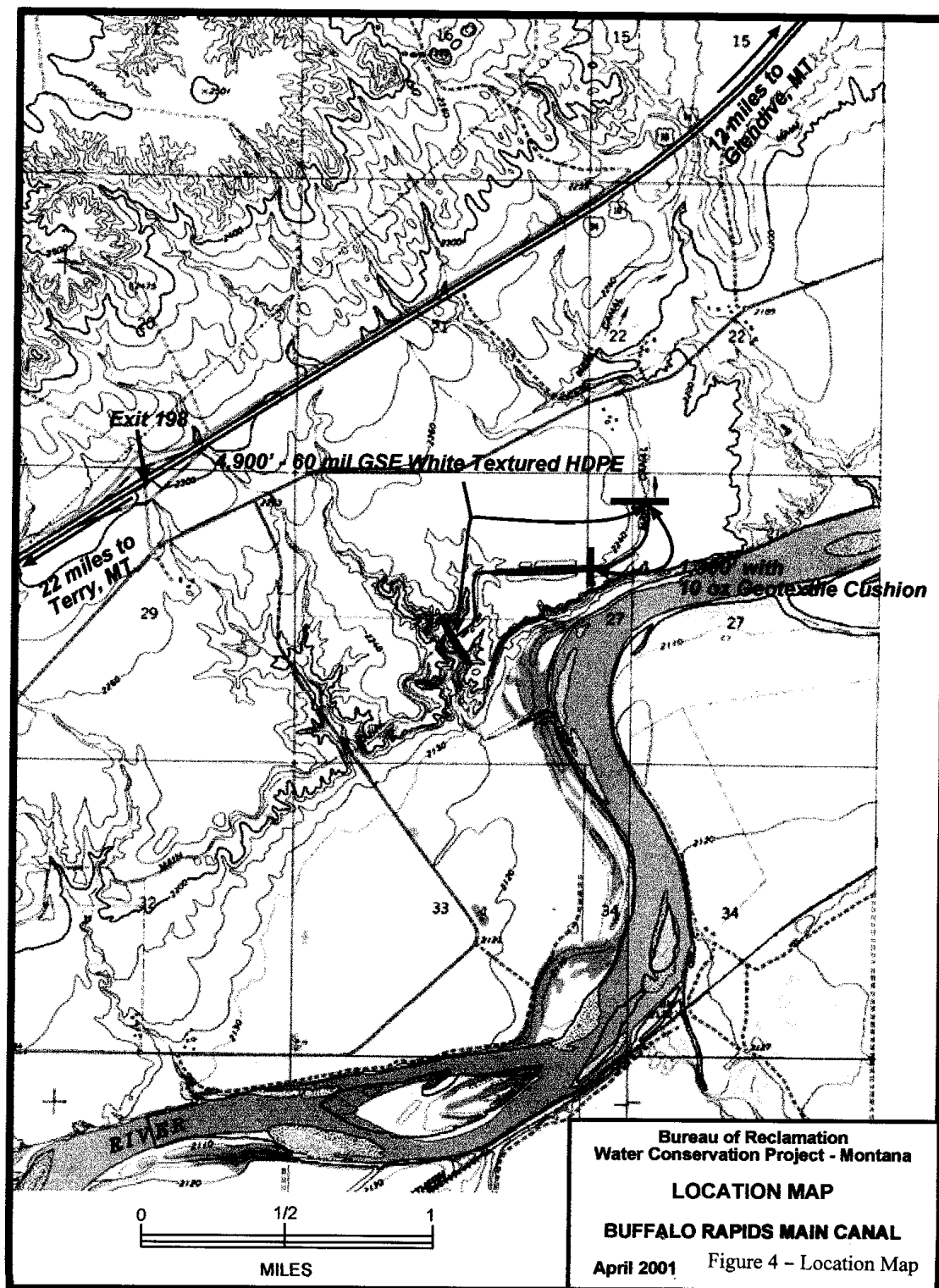
Photograph 22.—The anchor trench has been backfilled up to the edge of the canal.



Photograph 23.—Finished Colas test section.

Test Section BU-1.—

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| Material: | 1a = Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion 1b = Exposed 60-mil White Textured HDPE |
| Date Installed: | April 2001 |
| Location: | Buffalo Rapids Irrigation Project, near Glendive MT (figure 4) (4900 linear feet, 189,500 ft ² geomembrane, 57,400 ft ² geotextile) |
| Description: | The 60-mil textured HDPE geomembrane is coextruded with a white surface on one side and a black surface on the other. The geomembrane is installed with the white side up. Geotextile (where used) is a 10-oz needle-punched, nonwoven (Synthetic Industries 1071). Material data sheets are included in appendix A. |
| Prime Contractor: | Buffalo Rapids Irrigation Project |
| Material Supplier: | GSE Lining Technology Inc. |
| Surface Preparation: | <p>The irrigation project performed extensive subgrade preparation by removing vegetation to 1 foot above the waterline, restoring the approximately 1½:1 to 2:1 side slopes, and cutting a 2-foot-wide bench for anchoring on each bank. The side slopes are approximately 1½:1 through the cut, and approximately 2:1 before and after the cut. The cost of subgrade preparation is estimated at \$0.26 per ft², based on the subgrade preparation costs on previous similar test sections. The finished canal prism measures 38 to 40 feet across, including the 1 to 2 feet of material buried in the anchor berm on each bank. The finished canal invert is 12 to 13 feet across, and the side slopes are 5 to 6 feet high. Water typically runs about 4 to 5 feet deep, and this section of canal typically carries about 200 cfs. Seepage is suspected to cause erosion on the face of a bluff over the Yellowstone River south of the canal. The downstream 1,300 feet of the test section contains cobbles and large rock and was previously lined with asphalt during the original construction in 1941.</p> <p>The irrigation project also improved the access road along the north side of the canal through the cut. These costs are not included in the cost estimates.</p> |
| Construction: | An eight-man crew (including two machine operators) installed the geomembrane. The crew first rolled out the 15-foot-wide geotextile cushion in the road, and then pulled it into place in the canal invert. The HDPE geomembrane is manufactured in 22½-foot-wide rolls. The rolls were unrolled across the canal by a trackhoe operating in the canal invert. The geomembrane was temporarily secured with sandbags and 1-foot-long pins. Working from the access road, a second trackhoe then covered the anchor berm with 1 to 2 feet |



of cover soil and rock. The geomembrane panels were shingled downstream, overlapped 4 to 6 inches, and hot-wedge welded. Before seaming, the geomembrane was cleaned to remove any dirt and mud. GSE provided two men for the seaming operation.

The subgrade of the downstream 1,300 feet of the test section contains large numbers of rounded river rocks in the subgrade of up to 6 inches in diameter. The subgrade became less rocky in the upstream direction. Therefore, the lower 1,300 feet of the test section was covered with a 10-oz geotextile cushion. The cost estimates include both options.

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| Difficulties: | The textured geomembrane snagged on the geotextile cushion. For future application, a smooth geomembrane is recommend when using a geotextile cushion. Also, problems were experienced removing the thick vegetation above the waterline. Heavy rains during installation caused problems with water in the canal invert. A pump and wet-vac were used to dry out the canal invert before seaming. The contractor used a rub sheet to keep the liner clean during seaming and to provide a cushion over vegetation at the top of the side slope. |
| Unit Cost Estimate: | <p>Exposed 60-mil white textured HDPE with 10-oz Geotextile Cushion = \$1.22 per ft². (\$0.60 geomembrane + 0.10 Geotextile cushion + 0.26 surface prep + 0.10 installation +17% OH and profit)</p> <p>Exposed 60-mil white textured HDPE = \$1.12 per ft². (\$0.60 geomembrane + 0.26 surface prep + 0.10 installation +17% OH and profit)</p> |
| Advantages: | The white surface decreases surface temperatures and thermal expansion. The white on black surface also made it very easy to see any defects or tears in the geomembrane surface. The project can perform minor repairs using a \$500 hot air welder. |
| Disadvantages: | Lots of seaming was required because of the 22-foot roll width. Unrolling two rolls of geomembrane down the canal would reduce the amount of seaming, but would use about 10 percent more material. The Buffalo Rapids Project should consider purchasing a \$500 hot air welder to perform minor repairs. |
| Photographs: | 1 through 26 |

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 1.—Canal subgrade where geotextile cushion will be used. Small pieces of the old asphalt lining can be seen in the right foreground.



Photograph 2.—Canal subgrade through the "Deep Cut." Large dirt clods in the invert rolled down the embankment during road improvement.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 3.—Backhoe excavates the 2-foot-wide anchor berm located 1 foot above the water line.



Photograph 4.—Geotextile cushion was placed over rocky subgrade in the downstream 1,300 feet of the test section. The 10-oz geotextile is placed lengthwise down the canal.

Buffalo Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 5.—Starting at the downstream check structure, the geomembrane is installed perpendicular to the flow in the canal and overlapped downstream.



Photograph 6.—View of nearly complete installation in the downstream section.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 7.—When the wind came up, sandbags were needed to temporarily secure the geomembrane. Laborers shown filling the sandbags.



Photograph 8.—Large Trackhoe performs final trimming on the subgrade. Note the sandbags in position on the anchor bench.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 9.—Trackhoe operating in the canal invert to unroll geomembrane across the canal.



Photograph 10.—Crew assists in unrolling and placing of the geomembrane.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 11.—Trackhoe unrolls geomembrane while sandbags and 1-foot tell pins hold it in place on the anchor bench.



Photograph 12.—Trackhoe unrolls geomembrane up the other bank, where it will be cut to size and secured to the anchor bench.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 13.—Steel pin has been driven into the anchor bench to secure the Geomembrane.



Photograph 14.—Several panels have been installed across the canal and temporarily secured with sandbags. Geomembrane panels still need to be seamed, and the anchor bench needs to be backfilled.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 15.—Sandbags are removed and moved upstream as the trackhoe backfills portions of the anchor bench. Backfill is not placed in the immediate vicinity of areas to be seamed.



Photograph 16.—View from the top of the “Deep Cut” looking downstream.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 17.—Cut-off trench at downstream check structure is filled with concrete and measures about 5 feet wide and 2 feet deep.



Photograph 18.—Completed downstream cut-off trench.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 19.—Heavy rains deposited water in the canal invert. A small pump is used to remove water from the area of the seam.



Photograph 20.—Standing water and mud had to be removed from the liner before seaming.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 21.—Self-propelled dual-wedge welder used for seaming.



Photograph 22.—Welding technician applies pressure behind the wedge welder to remove small wrinkles in front of the wedge.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 23.—Damage caused by wedge welder that needs to be repaired.



Photograph 24.—After tacking the patch in place with a hot-air gun, edges of the patch are ground off.

Buffalo Rapids Irrigation Project – Test Section BR-1
Exposed 60-mil White Textured HDPE with 10-oz Geotextile Cushion



Photograph 25.—Welding Technician uses extrusion welder to apply patches to the geomembrane. Extrusion rod is white to match the liner.



Photograph 26.—Completed test section. All seams have been welded, and anchor bench has been backfilled.

Test Section BI-I.—

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| Material: | Exposed 20-mil EVA with 8-oz geotextile bonded to both sides |
| Date Installed: | October 2001 |
| Location: | Bitter Root Irrigation District, near Hamilton MT (figure 5) (900 linear feet, 4,500 square feet) |
| Description: | <p>The membrane is GeoComp Canal³ (Canal-Cubed) geocomposite. It is composed of a gray 8-oz geotextile cushion; 20-mil EVA; and a black, 8-oz, geotextile cover. Both polyester geotextiles and the EVA geomembrane are made from recycled polymer. The geomembrane composite is installed with the black geotextile facing up for UV protection. Material data sheets are included in appendix A.</p> <p>GeoComp also supplied some 12-30-12 geocomposite for this job. The 12-30-12 is composed of a black 12-oz geotextile cushion, 30-mil EVA membrane, and a black 12-oz geotextile UV cover. The 12-30-12 costs \$0.53 per square foot, and is probably better suited for exposed applications.</p> |
| Prime Contractor: | Bitter Root Irrigation District |
| Material Supplier: | GeoComp Inc. |
| Surface Preparation: | The irrigation district performed extensive subgrade preparation by removing vegetation to 1 foot above the waterline, removing large rocks, restoring the approximately 1½:1 side slopes, and cutting a 2- to 3-foot-wide bench for anchoring on each bank. The cost of subgrade preparation is estimated at \$0.26 per ft ² , based on the subgrade preparation costs of previous similar test sections. The finished canal prism measures 40 to 45 feet across. The invert is 12- to 15-feet and 7- to 8-ft deep. This section of canal typically carries about 300 cfs and runs about 6 feet deep. The finished subgrade is quite rocky, with rounded cobbles up to 6 inches in diameter. Seepage from the canal has been flooding fields and a house located immediately to the north of the canal. The only access road is on the north side of the canal. |
| Construction: | The geomembrane was provided in 24-foot-wide rolls that are 275 feet long. A four to six man crew (including a trackhoe operator) installed the geomembrane. Because the canal was accessible only from one side, the geomembrane was unrolled across the canal by a trackhoe operating in the canal invert. After the geomembrane panel was cut from the roll to fit to the canal width (45 to 50 ft), the trackhoe would unhook the lifting bar and use its bucket to place cover material on the far anchor berm. The trackhoe would then back up 24 feet, re-attach to the lifting bar, and unroll the next panel. Panels were shingled downstream and overlapped a minimum of 1 foot. Overlaps of 3 to 4 feet were typical because of the uneven subgrade and bends in canal alignment. At the end of each day, the trackhoe would drive out of the canal and backfill the near anchor berm. Lining started at the bridge and proceeded upstream. The District placed and seamed about 900 linear feet of |

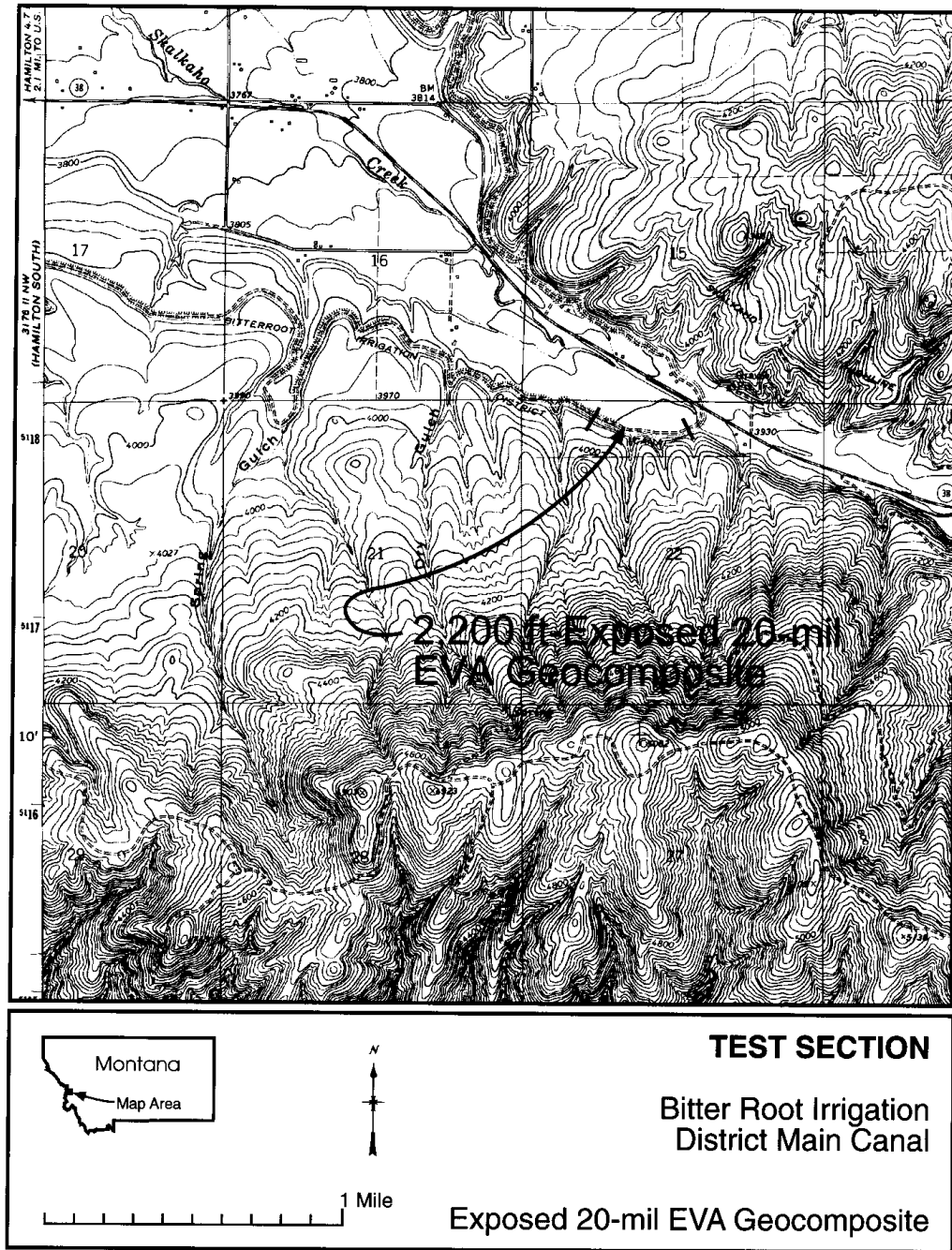


Figure 5.—Location map.

geomembrane liner in 3 days. The geomembrane was placed into a 2-foot-wide cut-off trench at the upstream and downstream ends. Another 1,300-foot section downstream from the bridge was too wet for lining at this time. As weather permitted, this downstream section was lined during the winter of 2001-2002, bringing the total test section to 2,100 linear feet.

Seaming was performed by a one to four man crew using an air-powered hot-glue gun provided by the geomembrane manufacturer. The hot-glue gun consisted of an air compressor, an air accumulator chamber, and the hot-glue gun. A generator powered the air compressor and the hot-glue gun. Glue was provided in hockey-puck-sized pellets. The pucks were loaded into a supply chamber and heated to 450 °F. The gun extruded a 1/4- to 1/2-inch bead of hot glue into the seam. The seam was pressed together and held closed for several minutes to allow the hot glue to cool and set. Occasional geomembrane wrinkles and fishmouths were simply folded over and glued down. Inspection of the seams found a few unbonded areas (typically 6 to 12 inches long) where the seam was not pressed (held) together long enough for the glue to cool and set.

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| Difficulties: | Seaming was quite slow, and the seams were inconsistent (unbonded areas) and relatively weak. The geomembrane manufacturer has a larger gun that places a 1-inch wide bead that would be more suitable for this material. The district switched over to hot roofing tar later in the week. The tar was supplied in a 100-gallon kettle. Hot-tar seaming was more labor intensive and relatively slow because of the time needed for the hot tar to cool and set. A hot-air welder may be another alternative for seaming this material. |
| Unit Cost Estimate: | Exposed 20-mil EVA-geotextile geocomposite = \$0.83 per ft ² (\$0.35 geocomposite + 0.26 surface prep + 0.10 installation + 17% OH and profit). |
| Advantages: | Installation was simplified by providing the geotextile cushion, EVA geomembrane, and geotextile cover in a single geocomposite. |
| Disadvantages: | Lots of seaming was required because of the 24-ft roll width. The seaming crew had trouble keeping pace with the installation crew. |
| Photographs: | 1 through 24 |

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photo 1.—The District performed extensive subgrade preparation by removing vegetation to 1 foot above the waterline, restoring the 1½:1 side slopes, and cutting a 2- to 3-foot anchor berm on each bank. The downstream section was too wet and was not lined at the time of the photograph.



Photograph 2.—Upstream section ready for installation of lining.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 3.—The prepared subgrade has large cobbles of up to 6 inches in diameter.



Photograph 4.—Trackhoe operating in the canal invert using a lifting bar to unroll geomembrane across the canal.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 5.—Trackhoe pulls down the far bank to cover geomembrane in the anchor berm.



Photograph 6.—At the end of the day, the trackhoe drives up the side slope and out of the canal.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 7.—Trackhoe prepares to backfill the near anchor berm.



Photograph 8.—Laborers help backfill the near anchor berm.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 9.—Backfill on near anchor berm is complete.

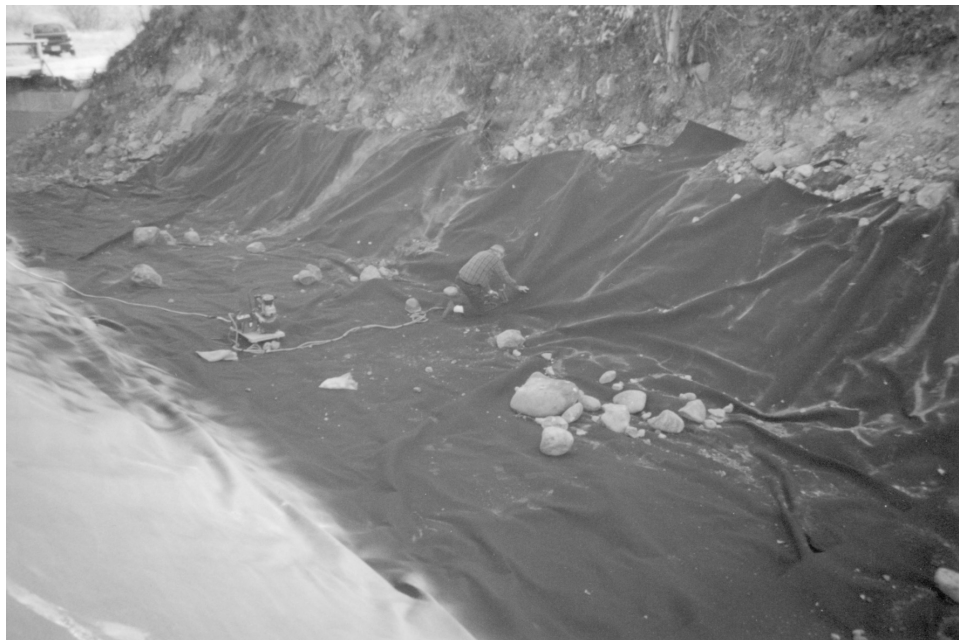


Photograph 10.—Overlapped seams are ready to be sealed. The trackhoe continues to lay geomembrane in the background.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 11.—Three-man crew removes dirt from the seam and seals it with hot glue. Seams need to be held shut until the hot glue cools and sets.



Photograph 12.—Seaming continues.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 13.—Closeup of the industrial hot-glue machine.



Photograph 14.—Closeup of seam with hot glue. Rock is placed on the seam to hold it together until the hot glue cools and sets.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 15.—Hot glue is extruded into the seam in a ½-inch bead.



Photograph 16.—Three-man crew cleans the seam (removes loose dirt), applies hot glue, and holds seam shut until the glue cools and sets.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 17.—Lower portion of Photograph shows factory seam in the upper geotextile. Fishmouth in the seam has been folded over and glued shut.



Photograph 18.—Hot tar was also used for seaming. Hot tar was supplied in a 100-gallon propane-fired kettle.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 19.—Geotextile is folded back, and hot tar is mopped onto both geotextile surfaces.

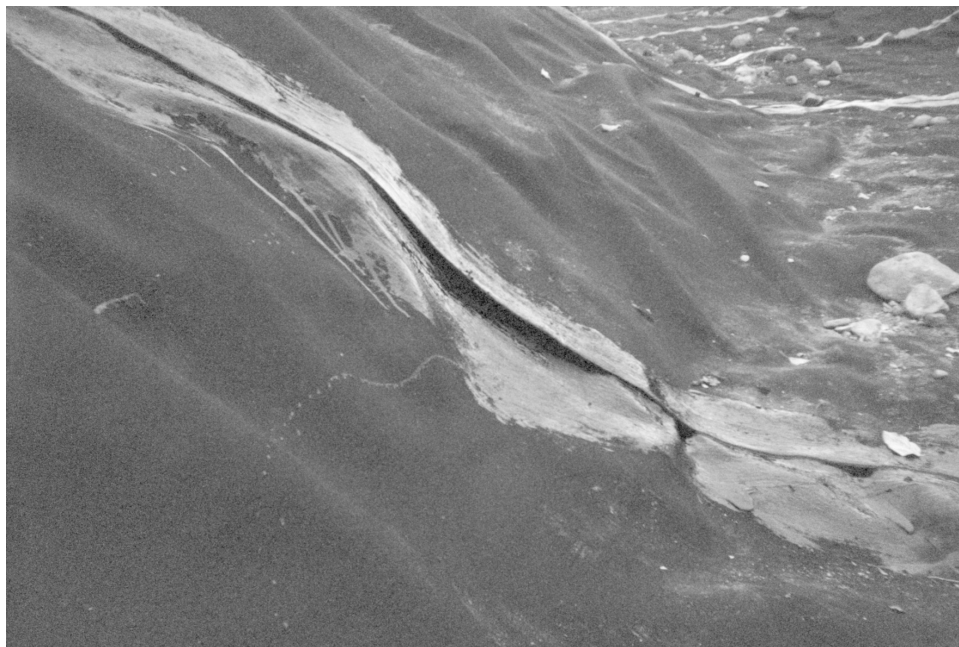


Photograph 20.—Upper geotextile is folded back into position, and the seam edge is buttered with hot tar.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 21.—Laborer on right uses hoe to hold seam closed while hot tar cools and sets.



Photograph 22.—Seam with hot tar pops open if not held closed for sufficient time.

Bitter Root Irrigation District – Test Section BI-1
Exposed 20-mil EVA with 8-oz Geotextile Bonded to Both Sides



Photograph 23.—Finished installation.



Photograph 24.—Finished installation.

